Res. Math. Nat. Sci. vol. 6, no. 1, pp. 12–18, 2026, doi:10.55657/rmns.v6i1.318

Research in the Mathematical and Natural Sciences
Journal Homepage: https://journal.scimadly.com/index.php/rmns
eISSN: 2828-6804

Original Research

A Comparison of Students' Mathematics Learning Outcomes through Problem-Based Learning and Direct Instruction on Cubes and Cuboids

Nur Fadlun Mohamad[1,*], Majid [1], and Abdul Wahab Abdullah[1]

[1]*Department of Mathematics Education, Universitas Negeri Gorontalo, Bone Bolango 96554, Indonesia*

Article information

***Corresponding author:**
Nur Fadlun Mohamad
fadlunmohamad@gmail.com

Received: 24 May 2026
Revised: 26 November 2026
Accepted: 28 November 2026
Published: 29 November 2026

Licensed under CC BY-NC-SA 4.0

Published by:
scimadly PUBLISHING

Abstract

Learning cubes and rectangular prisms requires students to connect spatial representations with problem-solving procedures. This study compared mathematics achievement between students receiving problem-based learning (PBL) and direct instruction. A pretest–posttest design involved two intact eighth-grade classes randomly selected from four classes at SMP Negeri 1 Paguyaman. Class VIII-1 received PBL and class VIII-3 received direct instruction, with 25 students in each class. Achievement was measured using constructed-response tests. Descriptive statistics and a posttest comparison based on summary statistics were employed. Mean pretest scores were 23.42 and 21.84 in the PBL and comparison classes, respectively, increasing to 73.80 and 63.60 at posttest. Mean gains were 50.38 and 41.76 points, respectively. The posttest difference was 10.20 points, with a standardized mean difference of Cohen's $d = 1.30$. A student-level t-test yielded $t(48) = 4.59$ (nominal $p < .001$), without accounting for classroom clustering. The PBL class demonstrated higher observed achievement than the comparison class. However, because each instructional condition was represented by only one class, the difference cannot be attributed exclusively to the instructional model. PBL warrants further evaluation as an alternative approach to teaching cubes and rectangular prisms in studies with replicated classrooms.

Keywords: Problem-based Learning; Direct Instruction; Mathematics Achievement; Solid Geometry; Junior Secondary School

1. Introduction

Mathematics learning requires students not only to perform calculations but also to understand mathematical concepts and apply them to problem-solving. The selection of an instructional model is important because it determines the opportunities available for students to construct their understanding and communicate their problem-solving strategies. The application of problem-based learning to algebraic expressions [1] and cooperative learning to matrices [2] illustrates efforts to improve learning processes and outcomes through the organization of student activities. Instructional strategies that promote active student participation [3] and the

selection of instructional models aligned with learning objectives [4] provide a foundation for developing learning activities that extend beyond teacher-centered knowledge transmission. In teaching set operations, Jupri et al. [5] reported higher learning outcomes among students receiving Quantum Teaching than those receiving direct instruction. Classroom action research conducted by Niode et al. [6] also demonstrated improvements in mathematical critical thinking skills across successive cycles through the implementation of Self Organized Learning Environment (SOLE). Both studies highlight the importance of organizing learning activities, although the instructional models and outcome measures differ from those examined in PBL research.

When learning about cubes and rectangular prisms, students need to establish connections between three-dimensional shapes, edge lengths, surface areas, and volumes. Mastery of mathematical formulas does not necessarily indicate an understanding of the relationships between the components of solid figures or the ability to select appropriate procedures for solving contextual problems. Therefore, learning activities that encourage students to identify relevant information, select appropriate representations, and explain their solutions are particularly relevant to the characteristics of this topic. Previous research on the application of PBL in science education [7] and mathematics learning outcomes in polyhedral geometry [8] provides a basis for examining instructional approaches to geometry. In plane geometry instruction, Polontalo et al. [9] reported that students receiving Contextual Teaching and Learning (CTL) demonstrated a better conceptual understanding of quadrilaterals than those receiving conventional instruction. Beyond instructional models, students' cognitive characteristics also warrant consideration. Patingki et al. [10] identified a positive correlation between cognitive styles and mathematical problem-solving abilities in number patterns. This correlational finding suggests that differences in students' mathematical abilities cannot be explained solely by instructional models.

Preliminary observations and interviews with mathematics teachers at SMP Negeri 1 Paguyaman indicated that students' examination scores frequently fell below the minimum mastery criterion (KKM) of 75. Teachers also reported limited student participation and a tendency among students to wait for explanations or answers from the teacher. These conditions provided a practical rationale for examining an instructional approach that offers students greater opportunities to actively develop problem-solving strategies.

Problem-Based Learning (PBL) uses problems as the starting point of the learning process. Students work to understand problems, develop alternative solutions, and discuss their findings, while teachers provide guidance as needed. Previous studies have compared PBL with direct instruction in teaching arithmetic sequences [11] and examined its application in senior secondary mathematics education [12], common tangents to circles [13], and social arithmetic [14]. Meta-analytical studies on mathematical reasoning [15] and mathematical problem-solving abilities [16] provide further empirical support for examining the application of PBL. A systematic review of secondary mathematics education also highlighted the potential of PBL to develop higher-order thinking skills while identifying challenges associated with the transition from direct instruction to problem-based learning environments [17].

Specifically in the context of cubes and rectangular prisms, Selfiani et al. [18] reported higher mathematical creative thinking abilities among students receiving PBL than among those receiving direct instruction using a posttest-only control group design. Although this study provides relevant empirical evidence on the same mathematical topic, creative thinking ability differs from overall mathematics achievement, and the research design did not measure changes in achievement from baseline conditions. The present study extends this evidence by examining students' achievement before and after instruction in two classes at SMP Negeri 1 Paguyaman. This study aims to compare the mathematics learning outcomes of students receiving PBL and direct instruction on cubes and rectangular prisms, with the hypothesis that students in the PBL class achieve higher mean posttest scores.

2. Methods

2.1 Research Design and Participants

This study employed a quantitative approach with a two-group pretest–posttest comparison design. The population consisted of four eighth-grade classes at SMP Negeri 1 Paguyaman. Two classes were randomly selected, namely Class VIII-1 as the PBL class and Class VIII-3 as the direct instruction class. Each class consisted of 25 students, resulting in a total of 50 participants. Sampling was conducted at the classroom level rather than through individual student randomization. The random assignment procedure for allocating instructional con-

ditions was not described in detail; therefore, this study was treated as a comparison between two intact classes. The classroom served as the unit of instructional implementation, whereas individual students served as the units of outcome measurement. The research design is presented in Table 1.

Table 1: Research design.

Group	n	Pretest	Instruction	Posttest
VIII-1	25	O_1	PBL	O_2
VIII-3	25	O_3	Direct instruction	O_4

2.2 Instructional Implementation

Both classes received instruction on cubes and rectangular prisms using different instructional models. In the PBL class, the teacher organized students into five groups, each consisting of four to five students. Student worksheets (LKPD) were used to facilitate reading, understanding, discussing, and solving mathematical problems. The teacher provided guidance throughout the group discussions and problem-solving activities. Each group subsequently discussed its solutions and received feedback from other groups.

In the direct instruction class, the teacher explained the concepts of cubes and rectangular prisms, presented worked examples, and provided practice exercises using student worksheets. Students also participated in group activities under the teacher's guidance. The teacher assessed students' understanding and provided feedback. Thus, both classes used student worksheets and group activities but differed in the organization of instruction. PBL emphasized problems and student-led investigation as the starting point of learning, whereas direct instruction began with teacher explanations and worked examples.

2.3 Research Instruments and Data Collection

Mathematics achievement was measured using constructed-response tests administered before and after instruction. Instrument development involved construct validation, empirical validity assessment, and reliability testing using Cronbach's alpha. However, the number of test items, scoring rubrics, item validity results, and reliability coefficients were not reported numerically, preventing an independent evaluation of measurement quality. Test scores were used as indicators of students' mathematics achievement in the instructional topic.

2.4 Data Analysis

Descriptive statistics included means, score ranges, and standard deviations. Standard deviations were calculated as the square roots of the variances reported in the homogeneity test results. Mean gains were calculated as the differences between mean posttest and pretest scores. The difference in mean gains between the two classes was used as a descriptive indicator rather than an inferential measure of changes in individual student scores.

Normality was assessed using the reported L statistics and their corresponding critical values at a significance level of $\alpha = 0.05$. Homogeneity of variance was assessed using variance ratios. The posttest comparison was recalculated using an independent-samples t-test with pooled variance based on the sample sizes, means, and variances of the two classes. The two-sided p-value was reported as a nominal result, and Cohen's d was calculated by dividing the difference between the mean posttest scores by the pooled standard deviation.

Because only one classroom represented each instructional condition, the assumption of independence at the student level could not be established, and between-classroom variability could not be estimated. Consequently, the nominal statistical test was not interpreted as valid inferential evidence of instructional model effects across the population of classrooms. Analysis of covariance (ANCOVA) and individual-level gain score analysis were not performed because paired pretest and posttest scores were unavailable.

3. Results and Discussion

3.1 Mathematics Achievement Before and After Instruction

Mean mathematics achievement scores increased from pretest to posttest in both classes, as presented in Table 2. Before instruction, the difference in mean scores between the two classes was 1.58 points. After instruction, this difference increased to 10.20 points. The mean gain in the PBL class was 50.38 points, whereas

the direct instruction class achieved a mean gain of 41.76 points. The difference in mean gains of 8.62 points represents the relative change in achievement between the two classes.

Table 2: Descriptive statistics of mathematics achievement

Test / Class	n	Min–Max	Mean	SD*
Pretest PBL	25	17–27	23.42	2.86
Pretest direct instruction	25	14–29	21.84	3.92
Posttest PBL	25	57–86	73.80	7.92
Posttest direct instruction	25	53–81	63.60	7.78

*Standard deviations were calculated from the variances reported in the homogeneity test results: 8.17, 15.34, 62.69, and 60.59, respectively.

Although the PBL class achieved a higher mean posttest score, the mean scores of both classes remained below the minimum mastery criterion (KKM) of 75. The proportion of students who achieved the minimum mastery criterion could not be determined from the mean scores and score ranges alone.

3.2 Assumption Testing and Posttest Comparison

The L statistics for all score groups were below the reported critical value of 0.173, as shown in Table 3. The pretest and posttest variance ratios of 1.88 and 1.03, respectively, were also below the reported critical F value of 1.98. These assessments indicated no violations of the assumptions under the criteria employed, but they did not establish the independence of student observations within classrooms.

Table 3: Summary of the reported normality test results

Group	Calculated L	Critical L
Pretest PBL	0.1385	0.173
Pretest direct instruction	0.0910	0.173
Posttest PBL	0.0939	0.173
Posttest direct instruction	0.1131	0.173

Recalculation of the posttest statistics yielded a pooled standard deviation of 7.85 and a t-statistic of 4.59. The standardized mean difference of 1.30 indicates that the difference between the two class means was relatively large compared with the within-class variability in scores. A summary of the recalculated statistics is presented in Table 4.

Table 4: Posttest comparison based on summary statistics

Indicator	Value
Mean difference (PBL minus direct instruction)	10.20
Pooled standard deviation	7.85
t-statistic (df = 48)	4.59
Two-sided p-value (nominal)	< 0.001
Cohen's d	1.30

The reported p-value is nominal because the calculation assumes independent observations. Classroom-level replication was unavailable for either instructional condition, preventing a statistical comparison of the instructional models that accounts for between-classroom variability.

3.3 Discussion

The principal finding of this study was that the PBL class achieved higher posttest scores than the direct instruction class. This difference was evident not only in the final achievement scores but also in the improvement from baseline. The mean gain in the PBL class exceeded that of the direct instruction class by 8.62 points. This pattern supports the relevance of PBL as an instructional approach to cubes and rectangular prisms within the context of the two classes examined, although it provides insufficient evidence to establish the magnitude of the causal effect of the instructional model.

Differences in the organization of learning activities may help explain the observed achievement patterns. In the PBL class, students used worksheets to understand and solve problems before discussing their solutions with other groups. These activities provided opportunities for students to connect information presented in mathematical problems with geometric concepts, evaluate problem-solving strategies, and reconsider their solutions. In contrast, direct instruction began with teacher explanations and worked examples, with subsequent practice activities guided by procedures previously introduced by the teacher. These differences reflect the reported characteristics of the instructional activities rather than direct measurements of student engagement or cognitive processes.

The findings are consistent with previous research on PBL in teaching arithmetic sequences [11] and mathematics achievement more generally [12]. Studies on common tangents to circles [13] and social arithmetic [14] also demonstrate the application of PBL across different mathematical contexts. Meta-analytical studies on mathematical reasoning [15] and mathematical problem-solving abilities [16] are relevant because understanding problems and developing solution strategies are integral components of PBL. However, mathematical reasoning, problem-solving ability, and overall mathematics achievement represent distinct learning outcomes. Consequently, the findings of the present study cannot establish whether each of these skills improved independently. The results are also consistent with those reported by Selfiani et al. [18] on cubes and rectangular prisms, although their study specifically assessed mathematical creative thinking ability. The consistency of findings across studies addressing the same mathematical topic supports the relevance of PBL to solid geometry instruction but does not establish that students' mathematical creative thinking abilities improved in the present study.

The systematic review by Aba-Oli et al. [17] emphasizes that the implementation of PBL in secondary mathematics education involves not only cognitive outcomes but also the adaptation of teachers and students to inquiry-based learning activities. In the present study, the use of student worksheets in both classes indicates that the distinction between instructional conditions was not simply the presence of worksheets or group activities, but rather the organization of problems, explanations, and instructional guidance. However, systematic classroom observation data on implementation fidelity were unavailable, preventing a comprehensive comparison of the quality of implementation of the two instructional models.

From a practical perspective, the mean posttest score of 73.80 in the PBL class remained slightly below the minimum mastery criterion of 75. Therefore, higher relative achievement does not necessarily indicate that the expected level of learning mastery has been attained. Teachers may consider incorporating contextual problems, visual representations of solid geometric figures, discussions of problem-solving strategies, and feedback addressing conceptual errors into mathematics instruction. Individual assessment remains necessary to identify students who require further conceptual reinforcement and additional practice.

3.4 Research Limitations

This study involved only two intact classes, with one class representing each instructional condition. The influence of classroom characteristics, student interactions, and other classroom-specific factors could not be separated from the influence of the instructional model. The student-level t-test did not address this limitation. Differences in baseline achievement were not controlled through analysis of covariance because individual paired pretest and posttest scores were unavailable for reanalysis. Furthermore, the intervention duration, equivalence of instructional time, details of the scoring rubrics, and reliability coefficients were not fully reported. Future studies should involve multiple classrooms in each instructional condition, systematically document implementation fidelity, and employ analytical methods that account for baseline achievement and the hierarchical structure of student observations within classrooms. The generalizability of the findings is therefore limited to the context of the observed classes.

4. Conclusion

The class receiving Problem-Based Learning (PBL) achieved a mean posttest score of 73.80, higher than the mean score of 63.60 in the direct instruction class. The respective mean gains were 50.38 and 41.76 points, with a difference of 8.62 points. These findings demonstrate higher descriptive achievement in the PBL class on cubes and rectangular prisms. However, the inclusion of only one classroom per instructional condition limits causal

attribution and the generalizability of the findings. PBL warrants consideration as an alternative instructional approach to solid geometry, with further investigation through research designs incorporating classroom-level replication and well-documented individual-level measurements.

Declaration of Artificial Intelligence (AI) Use

The authors used ChatGPT (OpenAI) to assist with language editing, translation, manuscript organization, formatting, and verification of statistical calculations based on the available summary statistics. No AI-generated research data were used in this study. The authors reviewed and verified the AI-assisted content and take full responsibility for the accuracy, interpretation, and integrity of the manuscript.

Author Contributions

Nur Fadlun Mohamad: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing–original draft. **Majid**: Conceptualization, Methodology, Validation, Supervision, Writing–review and editing. **Abdul Wahab Abdullah**: Methodology, Validation, Supervision, Writing–review and editing.

Acknowledgments

The authors thank the principal, mathematics teachers, and eighth-grade students of SMP Negeri 1 Paguyaman for their cooperation and participation in this study.

Funding

This research received no external funding.

Data Availability

The summary statistics supporting the findings of this study are presented in the article. Individual-level pretest and posttest scores were not available for reanalysis during manuscript preparation.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Aswina, Y. Ismail, N. Katili, and Majid, "Penerapan Problem Based Learning untuk Meningkatkan Hasil Belajar Siswa Materi Bentuk Aljabar," *JEMS*, vol. 11, no. 2, pp. 501–507, 2023, doi: 10.25273/jems.v11i2.15916.

[2] P. Zakaria, N. Katili, and T. Damayanti, "Meningkatkan Hasil Belajar Matematika Siswa Pada Materi Matriks Melalui Penerapan Model Pembelajaran Kooperatif Tipe NHT," *Jambura J. Math. Educ.*, vol. 4, no. 2, pp. 148–157, 2023.

[3] Fitri and Rahma, "Penerapan Strategi The Firing Line Pada Pembelajaran Matematika Siswa Kelas XI IPS SMA Negeri 1 Batipuh," *J. Pendidik. Mat.*, vol. 3, pp. 18–22, 2014.

[4] Isrok'atun and A. Rosmala, *Model-Model Pembelajaran Matematika*. Jakarta: Bumi Aksara, 2018.

[5] R. Jupri, P. Zakaria, M. Majid, R. Resmawan, and D. R. Isa, "Pengaruh Model Pembelajaran Quantum Teaching Terhadap Hasil Belajar Siswa Pada Materi Operasi Himpunan," *Euler: Jurnal Ilmiah Matematika, Sains dan Teknologi*, vol. 10, no. 2, pp. 274–281, 2022, doi: 10.34312/euler.v10i2.16940.

[6] N. Niode, P. Zakaria, and R. Resmawan, "Implementasi Model Pembelajaran Self Organized Learning Environment untuk Meningkatkan Kemampuan Berpikir Kritis Matematis," *Indiktika: Jurnal Inovasi Pendidikan Matematika*, vol. 4, no. 2, pp. 62–75, 2022, doi: 10.31851/indiktika.v4i2.7615.

[7] Sulaeha, "Pengaruh Model Pembelajaran Berbasis Masalah (Problem Based Learning) Terhadap Hasil Belajar Siswa Kelas X SMA Negeri 1 Tamalatea Kabupaten Jeneponto (Studi Pada Materi Pokok Reaksi Reduksi Oksidasi)," *J. Chem.*, vol. 17, pp. 94–102, 2016.

[8] A. W. Abdullah, N. Achmad, and N. C. Fahrudin, "Deskripsi Hasil Belajar Matematika Siswa Melalui Pembelajaran Daring Pada Pokok Bahasan Bangun Ruang Sisi Datar," *Ilm. Mat. Sains dan Teknol.*, vol. 8, pp. 36–41, 2020, doi: 10.34312/euler.v8i2.10324.

[9] G. Polontalo, R. Resmawan, S. Zakiyah, and A. W. Abdullah, "Dampak Model Pembelajaran Contextual Teaching and Learning Terhadap Kemampuan Pemahaman Konsep Matematis Siswa Pada Materi Segiempat," *Jambura J. Math. Educ.*, vol. 4, no. 1, pp. 50–62, 2023, doi: 10.34312/jmathedu.v4i1.16766.

[10] A. Patingki, A. D. Mohidin, and R. Resmawan, "Hubungan Gaya Kognitif Siswa Dengan Kemampuan Pemecahan Masalah Matematika," *Jambura J. Math. Educ.*, vol. 3, no. 2, pp. 70–80, 2022, doi: 10.34312/jmathedu.v3i2.15412.

[11] Aznaim, Majid, and Nurwan, "Pengaruh Model Pembelajaran Problem Based Learning dan Model Pembelajaran Langsung Terhadap Hasil Belajar Matematis Siswa Pada Materi Barisan Aritmetika di Kelas X," *J. Soc. Sci. Res.*, vol. 4, pp. 10 833–10 844, 2024.

[12] Mente and Jazuli, "Pengaruh Model Pembelajaran Problem Based Learning Terhadap Hasil Belajar Matematika Siswa Kelas X SMA Negeri 9 Kendari," *J. Penelit. Pendidik. Mat.*, vol. 2, pp. 37–54, 2014.

[13] M. F. Paloloang, "Penerapan Model Problem Based Learning (PBL) Untuk Meningkatkan Hasil Belajar Siswa Pada Materi Panjang Garis Singgung Persekutuan Dua Lingkaran di Kelas VIII SMP Negeri 19 Palu," *J. Elektron. Pendidik. Mat. Tadulako*, vol. 2, pp. 68–75, 2014.

[14] T. A. Usman, K. Usman, F. A. Oroh, S. Zakiyah, A. W. Abdullah, and A. Kaluku, "Pengaruh Model Problem Based Learning Terhadap Kemampuan Pemecahan Masalah Matematika Siswa Pada Materi Aritmatika Sosial di SMP Negeri 2 Limboto," *Irfani*, vol. 17, no. 2, pp. 146–156, 2022, doi: 10.30603/ir.v17i2.2243.

[15] I. M. Fitriyah, N. H. P. S. Putro, and E. Apino, "Meta Analysis Study: Effectiveness of Problem Based Learning on Indonesian Students' Mathematical Reasoning Ability," *Jurnal Riset Pendidikan Matematika*, vol. 9, no. 1, pp. 36–45, 2022, doi: 10.21831/jrpm.v9i1.46447.

[16] S. Salsabila and E. C. M. Asih, "The Effect of Problem-Based Learning Models on Students' Mathematical Problem-Solving Ability: A Meta-Analysis," *Jurnal Pendidikan MIPA*, vol. 25, no. 2, pp. 864–877, 2024, doi: 10.23960/jpmipa/v25i2.pp864-877.

[17] Z. Aba-Oli, K. Koyas, and A. Husen, "Higher-Order Thinking Skills-Oriented Problem-Based Learning Interventions in Mathematics: A Systematic Literature Review," *School Science and Mathematics*, vol. 125, no. 3, pp. 214–231, 2025, doi: 10.1111/ssm.12676.

[18] S. Selfiani, T. Machmud, R. Resmawan, and Y. Ismail, "Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kreatif Matematis Siswa pada Materi Kubus dan Balok," *Res. Math. Nat. Sci.*, vol. 1, no. 2, pp. 30–36, 2022, doi: 10.55657/rmns.v1i2.66.